Predictions of Minimum Spark Ignition Energy and Quenching Distances for CH_4/H_2 and C_3H_8/H_2 Mixtures with Air

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R. P. Lindstedt, M. P. Meyer and E. M. Váos
Mechanical Engineering Department
Imperial College of Science, Technology and Medicine
Exhibition Road, London SW7 2BX, UK

I. A. B. Reid
BP Chemicals Ltd.
Research Laboratory, Sunbury
Chertsey Road, Sunbury-on-Thames
Middlesex TW16 7LN, UK

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FOREWORD

The Institute of Petroleum commissioned this report to determine when gas streams containing hydrogen as a component should be treated as hydrogen for the purposes of specifying electrical equipment.

It has long been recognised that the particular properties of hydrogen require very specialised electrical equipment to be used to prevent ignitions. Many industrial gas streams contain hydrogen mixed with hydrocarbon gases. Engineers have to decide whether equipment designed for hydrogen duty is needed (i.e. gas group IIC) or whether equipment designed to the less stringent standards for hydrocarbon gas groups IIA or IIB is suitable.

This report provides the justification for the cut-off value of hydrogen concentration used when specifying hydrogen certified equipment (gas group IIC) for gas mixtures.

Although it is believed that the adoption of the recommendations of this report will assist the user, the Institute of Petroleum cannot accept any responsibility, of whatsoever kind, for damage or loss, or alleged damage or loss, arising or otherwise occurring as a result of the application of this report.

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P Cleaver	BG Technology
H Crowther	BP
K Glynn	BP
P Nichols	Consultant
T Ramsey	Esso Petroleum Co. Ltd
D Stirling	Marathon Oil UK Ltd (UKOOA)
A Tyldesley	Health and Safety Executive
M Wansborough	Shell UK

Company affiliations are those that applied at the time the document was being drafted.

SUMMARY

The current Institute of Petroleum code for hydrocarbon /hydrogen/ air mixtures recommends a limit of 30% hydrogen content for hazard assessment studies. Mixtures with a hydrogen content below this limit are treated as ordinary fuels. The work reported here examines the validity of the 30% hydrogen limit for methane/hydrogen and propane/hydrogen mixtures with air.

The present investigation is based on simulations of transient, premixed, spherical laminar flames developing from weakly ignited flame kernels. The computations feature comprehensive detailed chemistry and transport. A representative selection of stoichiometric methane/hydrogen and propane/hydrogen mixtures have been studied. More reactive ternary mixtures - located on a line connecting stoichiometric methane/air and fuel rich hydrogen/air mixtures - have also been considered.

Minimum spark ignition energies and quenching distances have been derived through a simplified and economical approach based on flame properties extracted from fully transient flame kernel simulations. The results are in excellent agreement with experimental data for cases featuring pure fuels. Computed results for the full range of mixtures considered here indicate that the current 30% limit on hydrogen dilution is conservative. Rapid changes of quenching distances and minimum ignition energies caused by increasing amounts of hydrogen become apparent only for significantly higher hydrogen contents.

The results are compared with properties of known fuels, such as ethylene. The minimum ignition energies and quenching distances for methane/hydrogen mixtures thus approach that of ethylene at approximately 60% hydrogen content. For the case of propane, the corresponding hydrogen content rises to around 70%. Naturally, caution is required in interpreting these results. However, a modest relaxation of the current 30% limit would not appear unreasonable. A significant dependence of the quenching distances and the minimum ignition energies on the type of fuel considered is thus observed. It should also be noted that the calculations assume homogeneous fuel-air mixtures and in certain cases stratification effects may need to be considered.

The current study is limited to two selected fuels and their mixtures with hydrogen. To support the current study and confirm the effect of hydrogen addition over a wider range of compounds it is strongly recommended that the simulations are extended to include an olefin (ethylene) and a representative heavier hydrocarbon (heptane).